Saskatchewan Agriculture, Food and Rural Revitalization

FARM *FACTS*

Silage Storage Techniques

Introduction

Silage is the feedstuff resulting from the preservation of green forage crops by acidification. There are two main phases in the ensiling process. The first is the aerobic phase, which occurs in the presence of oxygen (air). The oxygen that is present in the forage, as it is placed into storage, is consumed by the plant material through the process of respiration. Under aerobic conditions, plant enzymes and microorganisms consume oxygen and burn up plant water-soluble carbohydrates (sugars), producing carbon dioxide and heat.

The first phase should be as brief as possible to maintain the quality of the silage. Excessive aerobic fermentation reduces the energy content of the silage and may cause heat damage to proteins.

The second or anaerobic phase begins when available oxygen is used up by respiration and aerobic bacteria cease to function. Anaerobic bacteria (bacteria that grow in the absence of oxygen) then begin to multiply rapidly and the fermentation process begins.

The best silage is produced when the most rapidly growing microorganisms are predominately of the lactobacilli species, as they produce lactic acid from the fermented plant material. Lactic acid lowers the pH of the silage. Fermentation completely ceases after three to four weeks when the pH becomes so low that all microbial growth is inhibited.

The ensiling process is illustrated in **Figure 1**.

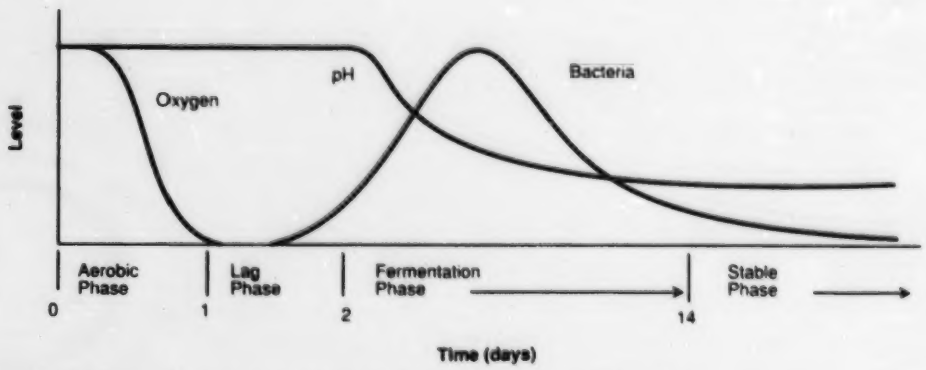

FIGURE 1. Short-term changes during ensiling of forage

Source: Nutritional Ecology of the Ruminant, P. Van Soest, Cornell University Press, 1994, p. 217.

There are several ensiling storage methods that will accomplish the ensiling process. All methods have advantages and disadvantages, and have widely ranging capital costs. Some methods of storing silage include trench, bunker, concrete silos, oxygen limiting silos, heap silage, and bale silage.

Whatever the system, the ensiling and storage system's main functions are to exclude air during the ensiling process and to prevent air from entering the silage during storage. Limiting air present in the silage will enhance feed quality and reduce spoilage. Slow silo filling, forage that is not chopped finely enough, inadequate packing and allowing air to enter stored silage all will reduce quality.

Efficiencies of some silage and other feed storage methods are outlined in **Table 1**, and **Figure 2**. Much higher losses can occur if good production practices are not followed, e.g., mending tears in plastic covers, using concrete floors, etc.

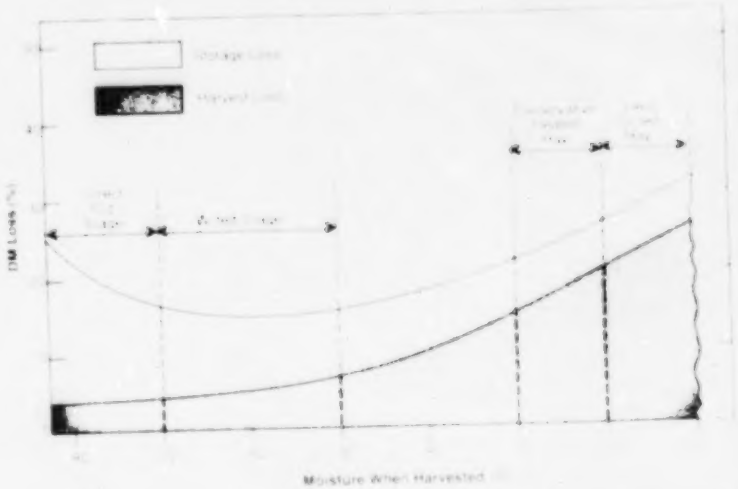

FIGURE 2. Loss of dry matter in relation to moisture content at harvest

TABLE 1. Estimated average losses (%) for various forage harvesting systems

Type of dry matter loss	Horizontal Pit/bunker 65% M.C.	Concrete tower 65% M.C.	Oxygen limiting tower 45% M.C.	Silage Bags (tubes) 65%	Round bale silage 65%	Square bale hay (Sheltered) 20% M.C.	Round bale hay (Outside) 25% M.C.
In field prior to harvesting	2	2	2	2	2	10	10
Harvesting loss	1-2	1-2	1-2	1-2	2-4	4-6	3-5
Storage loss	10-20	8-9	4	5-9	10-25	2	6-8
Feeding loss	4	2	2	4	4	4	5
Total	**17-27%**	**13-15%**	**9-10%**	**12-17%**	**19-34%**	**21-23%**	**24-28%**

Source: Forage Crops in the Aspen Parklands of Western Canada Harvesting AAFC 1991

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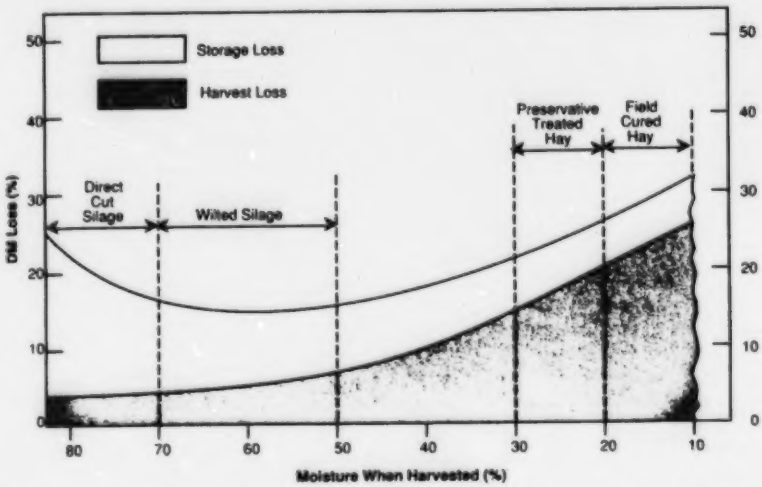

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Horizontal Silos

There are two types of horizontal silos – below ground level (i.e., pit or trench) and above ground (i.e. bunker and stack). The main advantage of horizontal silos is their low capital cost and suitability to feeding livestock in widely separated pens.

Trench silos are usually dug into a slope with the "downhill" end open for drainage and access. It is preferable to have the open end facing south. Earth walls should be sloped at a ratio of 1:2 to prevent caving in and to enable adequate silage packing. Where soil is unstable, it is necessary to line the walls with concrete or untreated wood. A convenient width for loading with a tractor and front-end loader is 15 metres (50 ft). A reinforced concrete floor sloped one to two per cent toward the open end will drain and stand up under high moisture from silage, rainfall and spring thaw.

Bunker silos are used in flat areas unsuitable for trench silos. Above-ground walls are constructed using concrete, earth or wood and braced with timbers or concrete buttresses. Round bales lined with plastic have also been used for bunker silo walls. Wood that comes into contact with silage should not be treated with preservatives. Permanent wood lining or walls should be covered with plastic to prevent moisture and acid penetration. Bunker silos require adequate drainage. Concrete floors are usually needed for easier loading and to minimize feed waste. Where earth floors are used, traffic must be limited (particularly animal self feeding).

When filling horizontal silos, maintain the front slope as steep as the packing tractor can climb without spinning. Silage layers should be added as quickly as possible. The layers are packed into place by a heavy tractor driven on the pile surface. The tractor compresses the silage mass forcing the air out. Pack promptly after adding material in layers less than two feet thick. A few inches is ideal. The packed surface should feel firm, not spongy, to walk on.

It can be difficult to pack the top one or two feet of cereal silage adequately. After a break in harvesting, add new silage before packing. The next load of silage added will seal air from the packed silage underneath.

Only experienced operators should pack on a horizontal silo. Packing tractors should be equipped with rollover-protected cabs. Wheels should be set as far apart as possible, tractor speeds should be slow and the tractor should be weighted to have a low centre of gravity.

Once the top surface has been properly packed, it should be covered immediately with six millimetre thick silage-grade polyethylene or reinforced plastic to prevent air or rainfall from entering the silage. Air entering silage causes spoilage and rainfall washes organic acids out of the silage, and introduces oxygen into the silage, increasing the pH and encouraging spoilage. White plastic is preferable, due to its superior UV resistance, reduced silage temperatures beneath it, and reduced freezing problems during winter.

FIGURE 3. Four-wheel drive tractors with dual wheels are effective and stable silage packers

Cover silage as the silo is filled. If filling stops for a significant length of time, the partially filled silo should be completely covered. The plastic cover must be held in place so air cannot enter the silage. A continuous layer of used tires works well for this purpose. If they are not continuous, the plastic may move in the wind and tear. Straw bales or chopped silage may also be spread over the plastic. Another method is to use a fish net or twine mesh to hold the plastic tightly over the silage, or placing rows of sand bags every three to 6 m (10 to 20 ft).

Try to plan silo and plastic sheet size to avoid seams. Seams and edges in the plastic cover must be sealed. A seal can be made with a 45 centemeter (18 in) overlap of the plastic sheets set into a groove in the silage surface. The seam is then covered with soil. Seams can also be sealed using heavy-duty, double-sided tape compatible with the plastic being used. Check with the plastic supplier for suitable products.

Covers should be inspected regularly to repair tears with tape. The edges of a horizontal silo must be kept sealed since shrinkage leaves a space along the walls. Because silage stacks and most bunkers have a large surface compared to the volume contained, covers are especially important to keep losses low. The spoiled silage on the surface of a 14 m x 28 m (40 x 80 ft) silo is estimated to be worth six times or more than the cost of a plastic cover.

The correct height and width to make a silo depends on daily silage usage based on the removal of a minimum of 10 cm (4 in) per day from the silage face. Removing less silage leads to spoilage or freezing problems. The silo should be as high as possible to minimize silo width, thereby minimizing surface spoilage. Increased silage height aids in packing. However, silo height is limited by the reach of unloading equipment and wall construction.

A minimum width is 9 m (24 ft) for front-end loader work. Silo length depends on the total silage needed annually. Some horizontal silo capacities are included in **Table 2**. Silo capacities are only estimates, as the amount of packing, dry matter content of the material, length of chop and silage material will affect the storage capacity of silage/haylage in all types of storage structures.

Stack Silage

Silage stacks are best used for storing an unexpected surplus of forage or as an interim method when first trying silage. Stacks should be located in an area sheltered from the wind and have a 15 to 30 cm slope away from the stack location. Stack width should be fitted to the size of plastic cover to be used. For instance, if a 13 X 33 m (40 X 100 ft) plastic cover is being used, the base of the pile should be 9 to 10 m (27 to 30 ft) in width.

The leading edge of the stack should be maintained at a 30-degree angle and packed lengthwise with a tractor. The entire stack should be covered during breaks in harvesting and the end uncovered when harvesting resumes. Since a stack has a large surface area exposed to oxygen and the weather, potential spoilage can be high. Prompt covering and effective anchoring of the cover is effective at reducing losses. The

Photo courtesy Agriculture and Agri-Food Canada

FIGURE 4. Silage stack being packed.

TABLE 2. Estimated Capacity of Horizontal Silos Containing 60-65% M.C. Silage*

			per 30 cm (1 ft.)	20(60)	28(80)	35(100)
8 32 lb/ft^3 (density ranges from 30 to 36 lb/ft^3)	10(30)	1.15	3.45	168	233	297
12 36 lb/ft^3 (density ranges from 34 to 38 lb/ft^3)	12(36) 17(48) 20(60)	2.33 3.11 3.88	7.0 9.33 11.66	335 448 559	476 634 792	615 820 1026
16 40 lb/ft^3 (density ranges from 37 to 42 lb/ft^3)	12(36) 17(48) 20(60)	3.45 4.60 5.76	10.36 13.82 17.28	456 608 760	663 884 1106	871 1161 1451

* Capacities are dependent on average densities of silage. Silage density increases with increasing moisture content, shorter cut length, packed silage depth and amount of packing.

** Capacity is calculated on the assumption that the far end at the silo is vertical and the front has a two to one slope (i.e., twice as long as the height of silage in the silo).

Source – Silage storage, M.E. Bellman, Silage Seminar'76, Saskatoon, 1976.

use of a large stack also minimizes the amount of surface spoilage.

The most efficient shape is a domed stack. This also permits tractor packing over the entire surface. The packing tractor must be operated carefully. The width and length of the stack are also affected by the removal rate for feeding. At least 10 cm (4 in) should be removed daily, to minimize spoilage.

Haylage

Haylage is made using conventional round or medium square balers to package high moisture forage. The forage is then enclosed in a plastic cover, bag, wrap, or tube to exclude oxygen to complete the fermentation process. Haylage systems are very flexible, have low capital requirement, low labour requirements and lower fuel costs, compared to chopped silage, while offering the potential reduction in dry matter and weather losses that silage systems offer. However, the variable costs are high, due to the cost of the plastic required to seal the haylage; and spoilage in the system can be high if care is not taken to adequately seal out oxygen during the wrapping process and during storage. Disposal of used plastic is also a problem.Haylage can and should be fed in conventional round bale feeders, to reduce wastage. Forage can be cut and conditioned in the same manner that a hay crop is harvested. The crop is field wilted to 40 to 60 per cent moisture and then baled. Baling forage at the correct moisture content is important – baling material that is too dry will result in poor fermentation and increased storage losses, and baling too wet reduces the amount of dry matter stored in each bale, thereby increasing costs.

Haylage can be produced using baling equipment that can produce a bale with a weight of 590 to 730 kilograms (1300 to 1600 lbs). See **Table 3**. Bales heavier than 730 kg (1600 lbs) put excessive strain on baling and handling equipment and are unsafe to handle. Round bales 1.5 m (4 to 5 ft) in diameter and 50 per cent dry matter weigh approximately 900 kg (2000 lbs).

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Silage Depth (ft) Average silage density (lb/ft^3)	Silo Width M (feet)	Silage Removal per 10cm (4 in.) tonnes	Silo Capacity (tonnes)**			
				Silo Length m(feet)		
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	20(60)	3.88	11.66	559	792	1026
16 40 lb/ft^3 (density ranges from 37 to 42 lb/ft^3)	12(36)	3.45	10.36	456	663	871
	17(48)	4.60	13.82	608	884	1161
	20(60)	5.76	17.28	760	1106	1451

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Table 3. Effect of bale diameter and moisture content on bale weight kg(lbs)

Bale diameter ft.	Moisture % 20	40	55	65
4	364 (800)	482 (1,060)	636 (1,400)	818 (1,800)
5	454 (1,000)	591 (1,300)	773 (1,700)	1045 (2,300)
6	568 (1,250)	727 (1,600)	1000 (2,20 0)	1273 (2,800)

Source: Manitoba Agriculture

Some balers may require modifications to make round bale silage. Bales should be encased in plastic as soon as possible after baling to maintain quality.

The bagging process involves elevating the bale and pulling the bag over the bale. The bag is then pulled tight and double tied. Placing the bales in the bags, excluding air and moving bales into storage is challenging work. Bale wrapping involves using a bale-wrapping machine to encase the bale in one mil plastic. Generally, the plastic should be overlapped 50 per cent to ensure an airtight seal and wrapped twice. The plastic is stretched 50 to 55 per cent to attain the desired tension.

Round bales can also be stored in plastic tubes by using shop built or commercially produced equipment. In either case, a frame holds the end of the plastic tube and is moved ahead to pull the plastic over the next bale. Securing loose plastic is important to reduce tears and subsequent haylage spoilage. Round bales can also be stacked and covered with plastic. A 13 X 33 m (40 X 100 ft) plastic sheet will cover 100 to 125 round bales stacked in a four-three-two configuration. It is difficult to exclude all of the air in this system, so it has a greater potential for spoilage. A shop vacuum can be used to remove air from beneath the cover.

Spoilage will rapidly occur in the remaining silage when the cover is removed during warm weather for feeding. Therefore, covered bale silage is best fed during winter. To avoid freezing of bales during winter, only remove and feed what will be consumed within a couple of days.

Air cannot be totally excluded in any of the bale silage storage techniques; therefore, the fermentation and ending pH level can be quite high, sometimes over five. Mould growth is also a problem. Table 4 lists the drop in pH level to be considered a prerequisite to the successful preservation of silage.

Use only top quality, seamless, UV (resistant plastic products. Generally speaking, silage makers can only be used once, especially in the case of round bales.

Photos courtesy Manitoba Agriculture

FIGURE 5. Several types of tubers are available commercially.

Table 4. pH levels in relation to fermentation period and silage type

Fermentation days	Bale silage	pH Chopped silage
0	5.9	5.9
3	5.8	5.8
4	5.7	5.6
9	5.5	5.0
60	5.1	4.4

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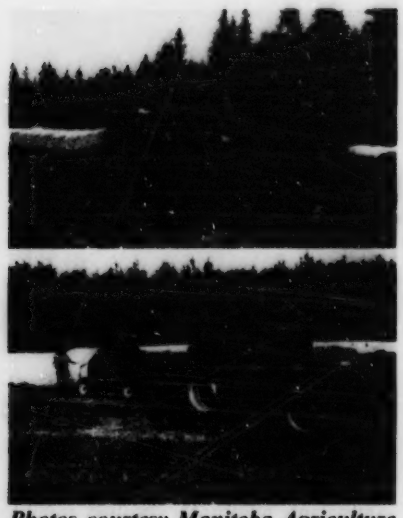
Air cannot be totally excluded in any of the bale silage storage techniques; therefore, the fermentation and ending pH level can be quite high, sometimes over five, which makes the silage particularly vulnerable to spoilage (**Table 4**). The ability of the cover to exclude air is paramount to the successful storage of the silage.

Use only top quality, warranteed UV-resistant plastic products. Generally speaking, plastic products can only be used once, certainly in the case of wrapped bales.



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1	5.8	5.1
3	5.7	4.9
9	5.5	4.6
60	5.1	4.4

Source: Manitoba Agriculture

Enclose bales as soon as possible after baling to prevent heating of bales. Inspect enclosed silage frequently to detect holes or tears in the covering, and patch with plastic tape designed for that use. Package and store the silage close to where it will be fed on a sloped, well-drained site. Locate rows of bales, or tubes perpedicular to the slope, for enhanced drainage.

Moving bales before they are to be fed may result in damage to the cover and subsequent spoilage; indeed some storage methods, such as tubes, cannot be moved after they are filled. Remove all surface irregularities from the storage site and remove vegetation and weeds, to reduce damage to plastic and rodent infestations.

Feeding Silage

In large feedlots, silage is usually distributed to the feed bunks with a mixer feed truck or a feed wagon. Loading the silage from a trench or bunker silo is accomplished with a front-end loader. The loader scrapes a slice from the silage face and loads the silage into a mixer feed truck or wagon. With a reasonable amount of care and attention, losses of silage between the silo and the animal should be less than four per cent. With small livestock operations, self-feeding of silage is sometimes used to reduce machinery operation costs. For self-feeding, cattle require a 25 cm (10 in) width of feeding space per head. Maximum silo height is 2.4 m (8 ft). In winter, at least 10 cm (4 in) should be consumed from the face of the silo each day to minimize losses (in summer, 15 cm or 6 in). Based on 50 head consuming 34 kg (75 lb) of 65 per cent moisture silage per day, a 12 m (40 ft) wide silo, 2.4 m (8 ft) high, would have 10 cm (4 in) removed each day. However, summer use would reduce silo height by one-third to remove 15 cm (6 in) of silage off the surface.

Limited feeding in winter will reduce height by approximately half, as more feeding space is required per head. The decreased height means there is greater surface area relative to silo capacity; i.e., surface spoilage losses are a greater percentage of the total. Self-feeding often results in animals wasting feed. Systems based on self-feeding should be used with an understanding of the limitations of the method of feeding.

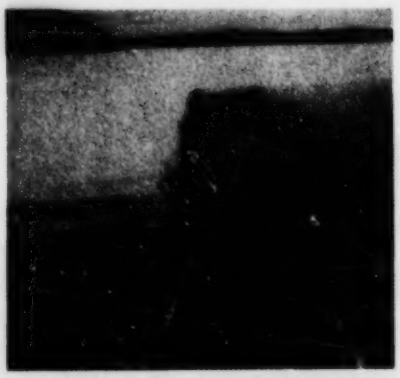

FIGURE 6. Barley haylage in a tube being used as winter forage.

Safety in Silage Making and Storage

A well-managed silage operation will normally avoid the circumstances that can set the stage for an accident to occur. Always take time to anticipate injury and life-threatening situations.

- Silage cutters and blowers have parts that continue to rotate after the power-take off has stopped. Only when the tractor power is shut off and the machinery has stopped rotating can the operator check the sharpness of cutter knives or clear plugged material.

- In horizontal silos the surface of silage being packed by a tractor is soft and unstable. The silage next to a bunker wall and the sides of silage stacks are particularly prone to giving way under a tractor's weight. Steep slopes, or digging the drive wheels into silage, can lead to backward overturn. The packing tractor should have a rollover protection cab, and the operator should wear a seatbelt.

- When nitrates are degraded in the ensiling process, nitrogen oxides are formed as products of microbial metabolism. The NO_2 which results when nitrogen monoxide contacts air is often called 'silo gas' and is highly toxic to man and animals when present in concentrations greater than 10 to 25 ppm. Always assume that both CO_2 (carbon dioxide), which can asphyxiate a human, and NO_2 (nitrogen

dioxide), which is poisonous, are present in a tower silo. Pulmonary edema occurs when the gas combines with water in the lining of the respiratory tract, causing pneumonia-like symptoms and death. Even if exposure is not fatal, respiratory tract damage can occur. Relapses are common after apparent recovery.

Since NO_2 is heavier than air, the brown gas is sometimes clearly visible inside silos or around silo openings. Most of the NO_2 is evolved from the silage in the first week of fermentation, with production peaking at two to three days after ensiling. Production of NO_2 essentially stops after the material has been in the silo for more than 10 days.

In one survey, 42 per cent of all silos tested contained NO_2 concentrations high enough to be considered hazardous to human health. Silo gas, therefore, must be expected in silos. Precautions, such as never entering an upright silo without running the blower for at least 10 minutes to circulate the air and only entering with an approved breathing apparatus, should always be taken.

Determining Moisture Content Using a Microwave Oven

1. Cut a representative cross-section of forage from the windrow.
2. Cut into 0.6 cm (1/4 in) pieces.
3. Weigh 100 grams of material and place on a paper plate or bag.
4. Spread sample out evenly and place in microwave over on high heat for three to four minutes
5. Weigh sample and record weight.
6. Stir sample and place in microwave oven on high heat for one minute. Reweigh and record weight.
7. Repeat step six until weight loss is less than one gram. This is the dry weight.

Calculation: wet wt. grams – dry wt. grams /100 = percent moisture

Determining Moisture Content of Forage by Hand Method

Water easily squeezed out and material holds shape	80+
Water can just be squeezed out and material holds shape	75-80
Little or no water can be squeezed out but material holds shape	70-75
No water can be squeezed out and material falls apart slowly	60-70
No water can be squeezed out and material falls apart rapidly	60 or less

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